LIFE CYCLE PRODUCTION AND COSTS OF A RESIDENTIAL SOLAR HOT WATER AND GRID-CONNECTED PHOTOVOLTAIC SYSTEM IN HUMID SUBTROPICAL TEXAS

OUTLINE OF PRESENTATION

- context
- presentation of systems
- annual production
- life cycle production
- economic performance

J.F. SWEENEY, JULY 9th 2015
NREL SAM VIRTUAL CONFERENCE

THE DWELLING

- 6,200 sq. feet home in Houston, Texas (south eastern Texas, climate is humid subtropical)
- Insulated concrete wall system with radiant barrier on entire building envelope
- Super durable roof, with sealed attic (unconditioned)
- Efficient heat pumps
- Solar thermal system (dom. hot water)
- Grid-tied Photovoltaic system (3.5 KW)
- Low flow faucets and toilets
- Rainwater harvesting with an underground collection cistern (7600 gallons)
- Building constructed in the Fall of 2009

LOCATION DATA

Site parameters

Elevation	13 m
Latitude	29.65 °N
Longitutde	-95.283 °E

Annual irradiance data

Global horizontal	4.28 kWh/m2/day
Direct normal	3.68 kWh/m2/day
Diffuse horizontal	2.01 kWh/m2/day
Avg temperature	21.1 °C
Avg wind speed	3.5 m/s

Figure 1. A satellite image of the renewable energy systems at the residence in Houston Texas: a photovoltaic system and a solar hot water system (Google Maps, 2014).

SOLAR PHOTOVOLTAIC SYSTEM

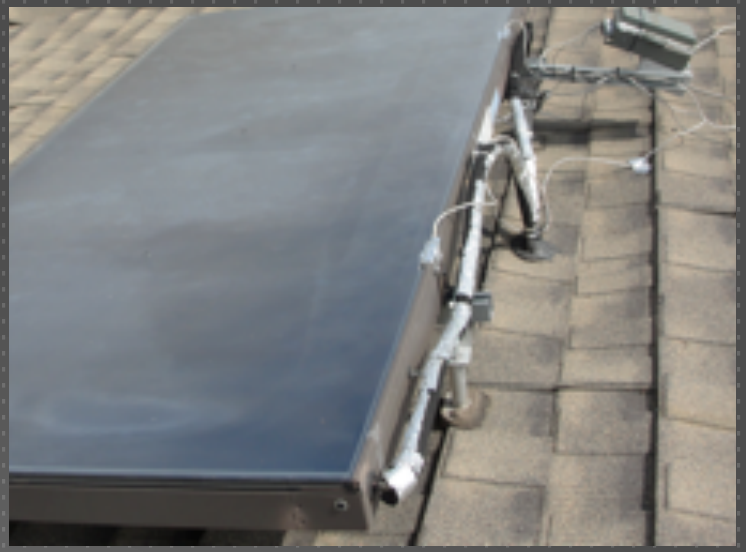
- Grid tied
- 20 - BP175 W Solar Panels
- Enphase MP175 Micro-Inverter on each panel
- Total Size – 3.5 kW
- Estimated to produce – 4,346 kWh/ year
- Mounted on the180° azimuth and at a 40° tilt

MICRO- INVERTER SPECIFICATIONS	
STC Input Power (DC)	210 W
Max Output Power (AC)	175 W
Nominal Current (AC)	750 mA
Peak Inverter Efficiency	95%

SOLAR HOT WATER SYSTEM

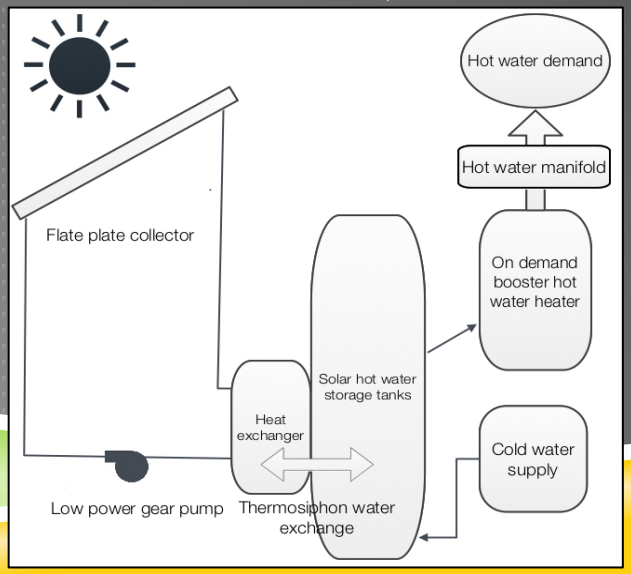
Energy Pack

- Heat transfer core
- Heat exchanger, manifolds, expansion tank
- 1/125 HP motor (23 W)/pump
- Controller starts pump if collector and storage tank is greater than 18 deg F
- Storage tank feeds demand hot water heater to makeup if necessary

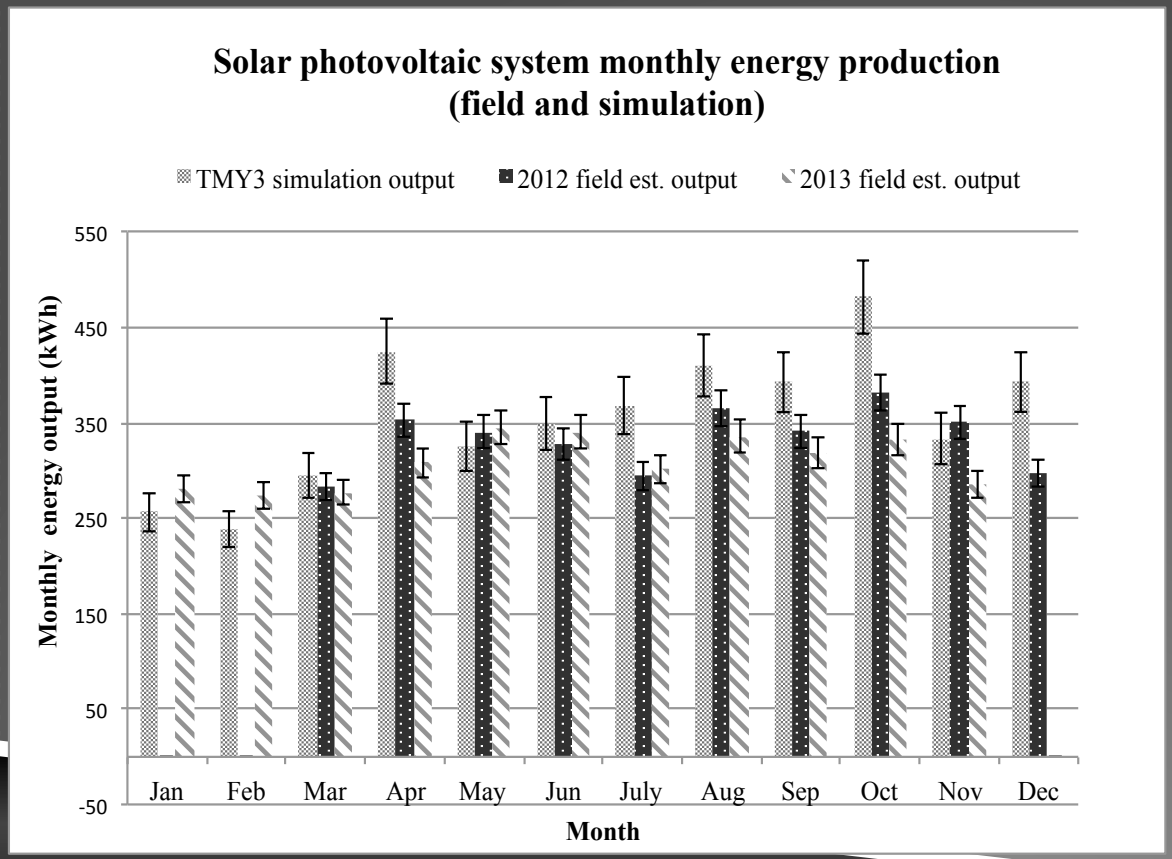


Flat Plate Collector

- Type: Liquid flat plate, 22° tilt, 270 ° azimuth
- Absorber: 0.5 mm Al sheet
- Dimensions: 4X8, Area: 2.874 m2

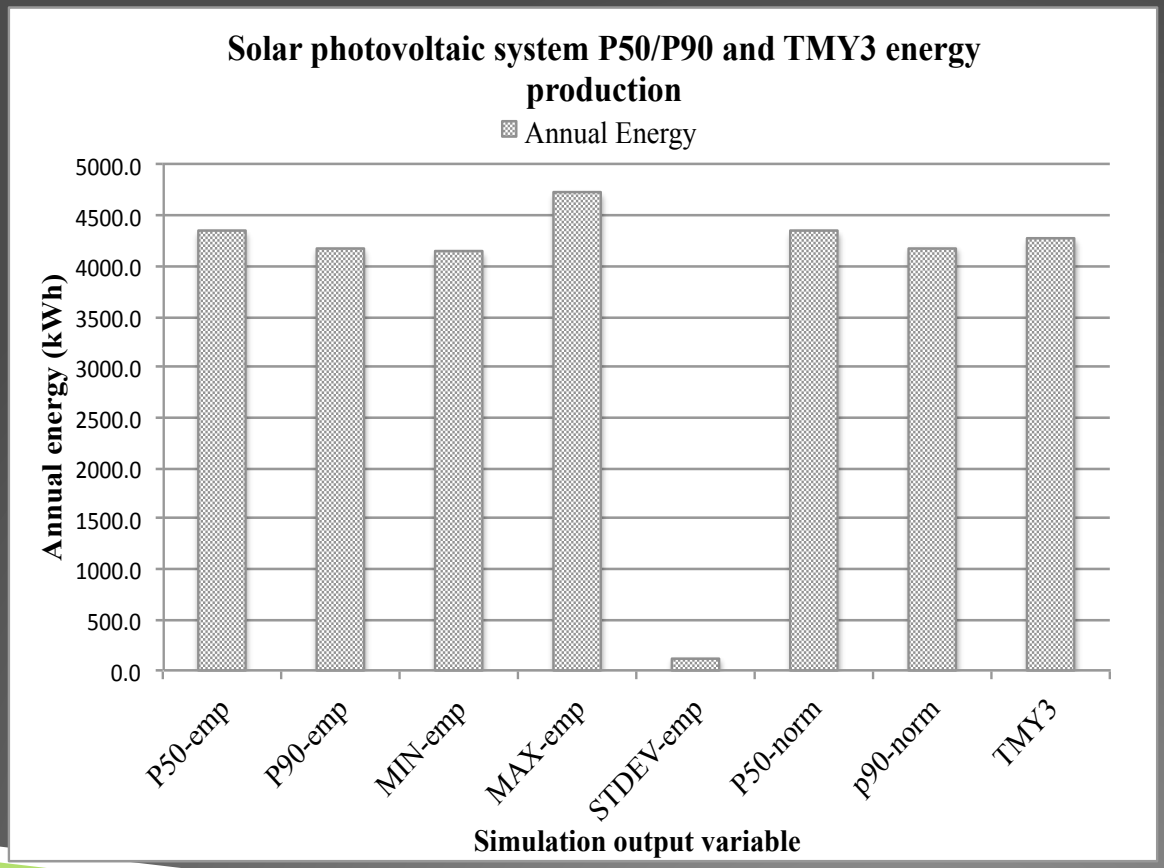


SPVS monthly energy production (field and simulation)



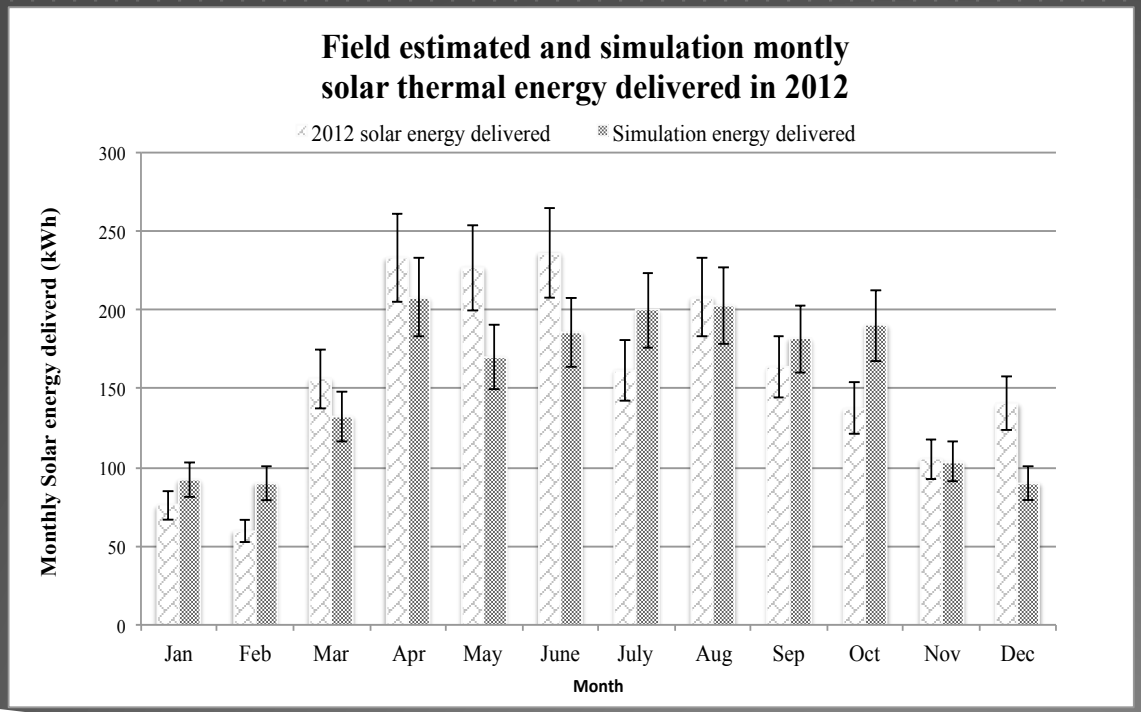
- Tilted surface radiation HDKR diffuse sky model with beam and diffuse irradiance components
- TMY3 weather data used in simulation
- Model uncertainties reported in literature 8-15%
- Measured uncertainty was estimated at 5%
- Model annual output within 6% (2012) and 12% (2013) of measurements

SPVS P50/P90 AND TMY3 ANNUAL ENERGY PRODUCTION COMPARISON



- Utilized SAM's simulation probabilistic tools with 30-YR NSRDB
- P50/P90 predictions illustrate consistent radiation on the 30-YR data set.
- TMY3 estimate consistent with P50/P90 predictions

SHWS monthly energy production (field and simulation)



- Tilted surface radiation HDKR diffuse sky model with beam and diffuse irradiance components
- TMY3 weather data used in simulation
- Hot water demand based on ASHRAE 90.2 - 4 people, 74 gal/day
- Model uncertainties reported 5.46% and 10% uncertainty (measured and simulated respectively)
- Model annual output within 3.5% (2012) of measurements

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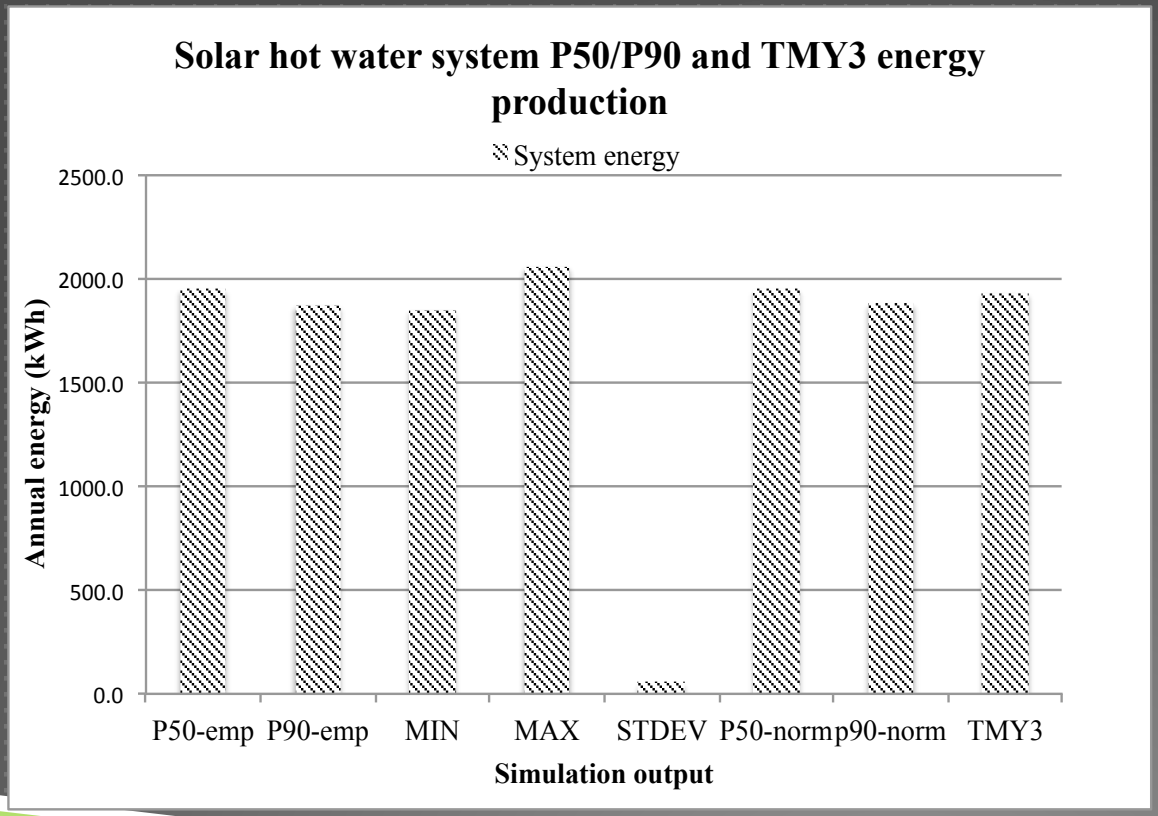

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SOLAR SYSTEMS INITIAL AND LIFETIME MODELED COSTS

Lifetime costs

Lifetime parameters	Unit	Solar photovoltaic	Solar hot water
Average lifetime	Years	30	30
Annual degradation	%	0.5	0.5
Annual maintenance	$/Year	$40	$40
Lifetime replacement costs	$/Avg Lifetime	$1,200	$600
Salvage value (% of original value)	%	15%	15%
Lifetime costs	$	$2,400	$1,800

Initial costs

PHOTOVOLATIC SYSTEM COSTS		
Description	Percent of total	Cost
Module	30.1%	$ 7,968
Inverter	13.3%	$ 3,525
Balance of equipment	18.1%	$ 4,782
Installation labor	18.6%	$ 4,912
Overhead and profit	19.9%	$ 5,262
Price		$ 26,448

SOLAR HOT WATER SYSTEM COSTS		
Description	Percent of total	Cost
Appliance and collector	47.2%	$ 3,000
Storage Tank	11.0%	$ 700
Mounting hardware, piping, etc ..	4.7%	$ 300
Installion	15.7%	$ 1,000
Overhead and profit	21.3%	$ 1,350
Price		$ 6,350

LIFECYCLE PERFORMANCE

Model assumptions

- 30-YR life cycle
- 0.5% annual degradation
- Gas burner efficiency 86%, Tank losses 20%

Solar energy system type	Annual energy production (kWh)	30-year lifecycle energy production (kWh)
Solar photovoltaic system	4,226	117,994
Solar hot water system (natural gas heating)	2,393	66,820
Solar hot water system (electric heating)	1,846	51,555

SPVS P90/P50 AND TMY3 LCOE, PAYBACK AND NPV

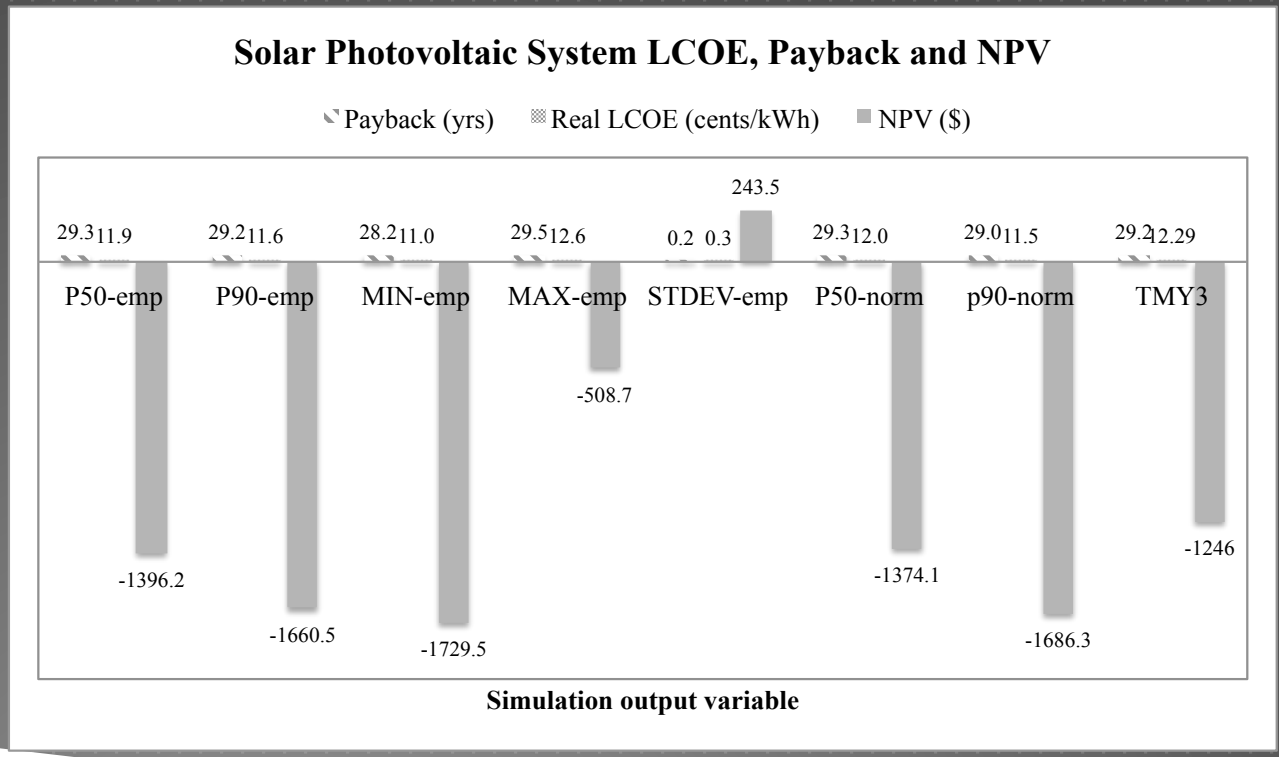
Economic performance indicators

- Payback
- Net present value (NPV)

$$NPV = \sum_{t=0}^{T} \frac{NBt}{(1+d)\,t}$$

- Levelized cost of energy (LCOE)

$$\text{LCOE} = \frac{\sum_{n=0}^{N} \frac{C_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{Q_n}{(1+d)^n}}$$



Model assumptions

- 30-YR loan at 4% IR, 100% debt fraction
- Discount rate : 4.4%
- Sales Tax : 8.25%
- Federal income tax: 33%

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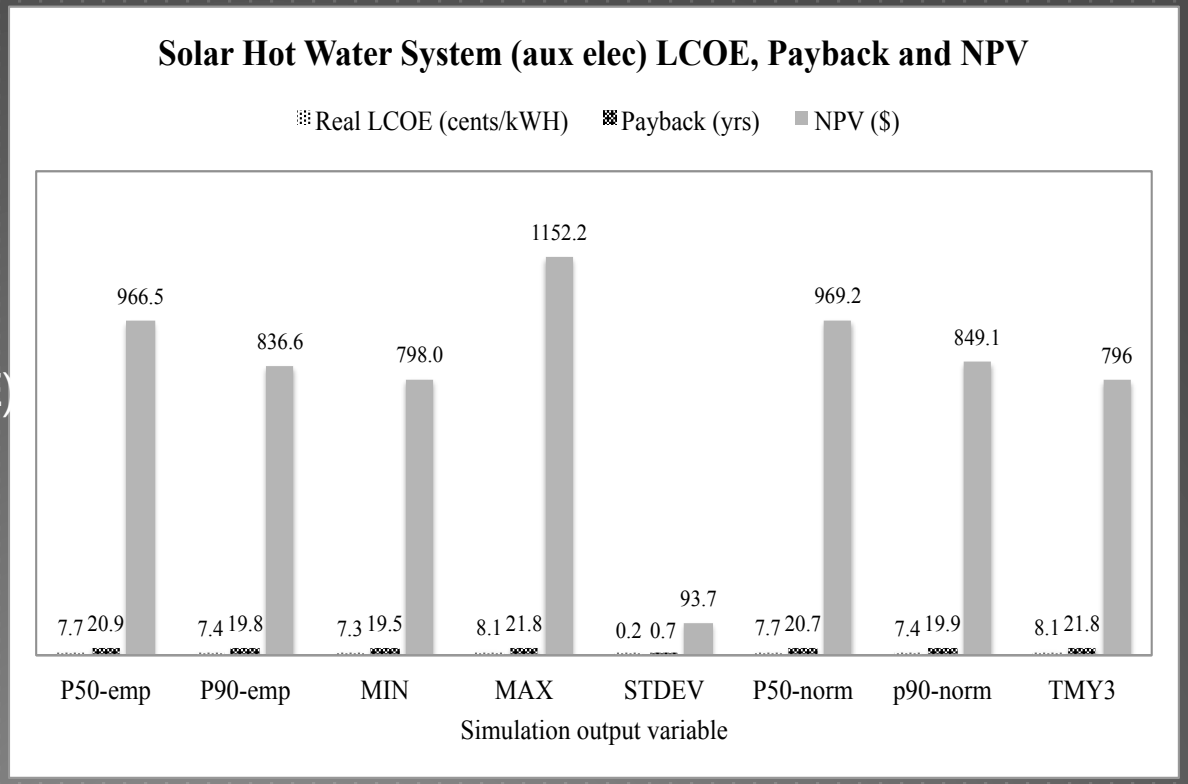

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REAL LCOE INITIAL COST SENSITIVITY